T-80060 * 08/06/2000

FIG. 1

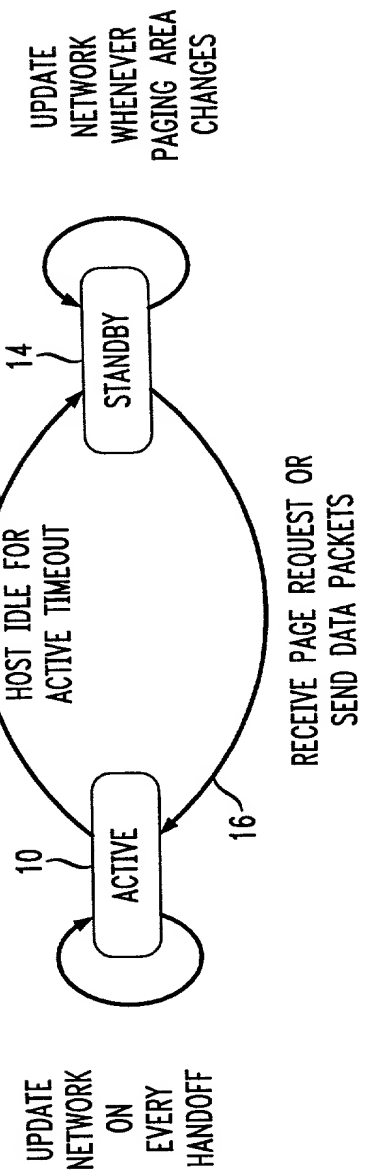


FIG. 2

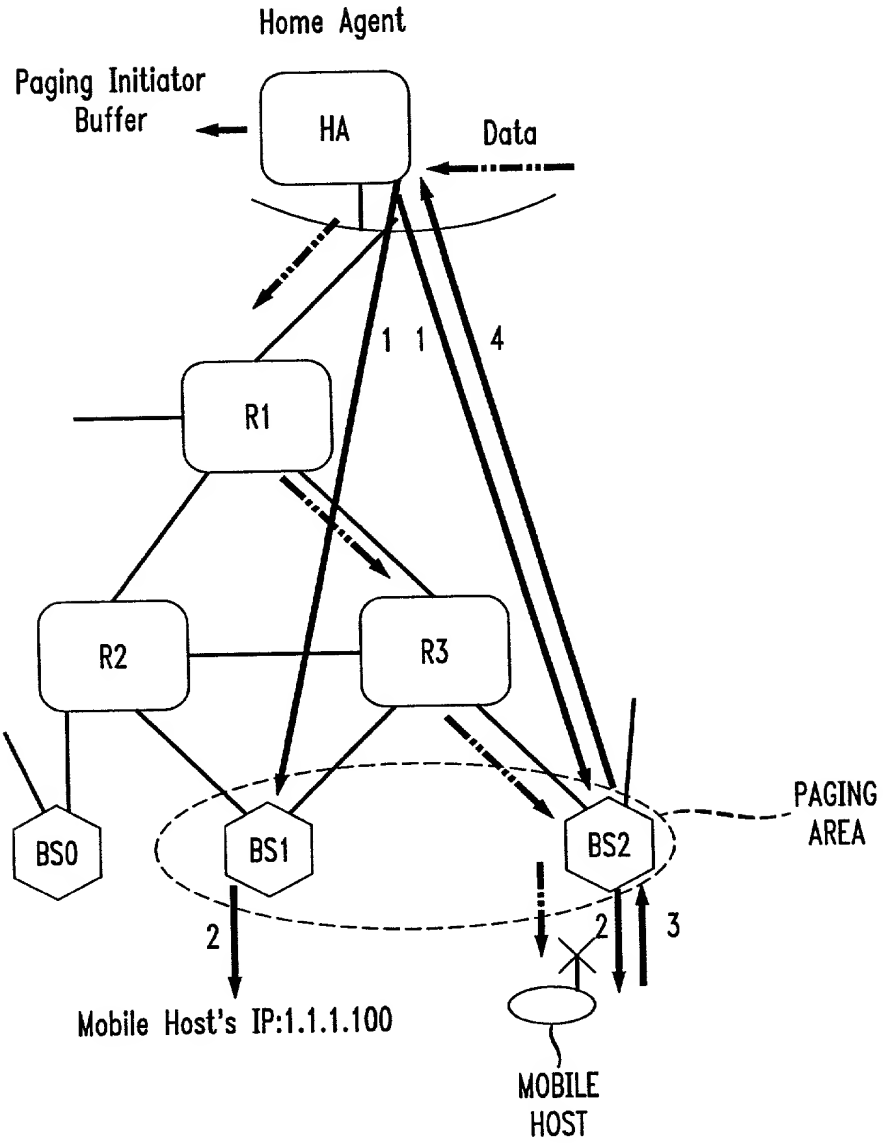

Home Agent
Paging Initiator Buffer
HA
Data
1
1
4
R1
R2
R3
BS0
BS1
BS2
PAGING AREA
2
2
3
Mobile Host's IP:1.1.1.100
MOBILE HOST

FIG. 3

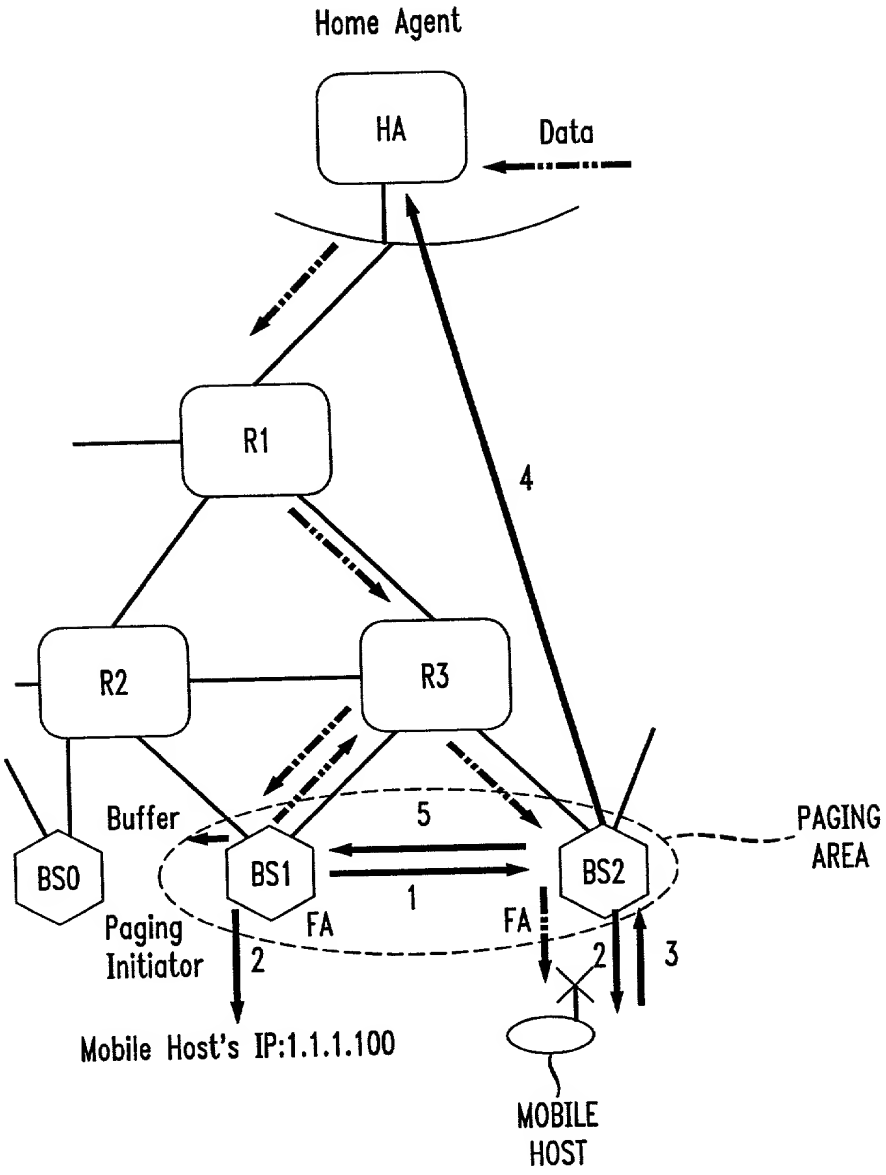

Home Agent
HA
Data
R1
4
R2
R3
Buffer
5
PAGING
AREA
BS0
BS1
BS2
1
Paging
Initiator
FA
FA
2
2
3
Mobile Host's IP:1.1.1.100
MOBILE
HOST

FIG. 4

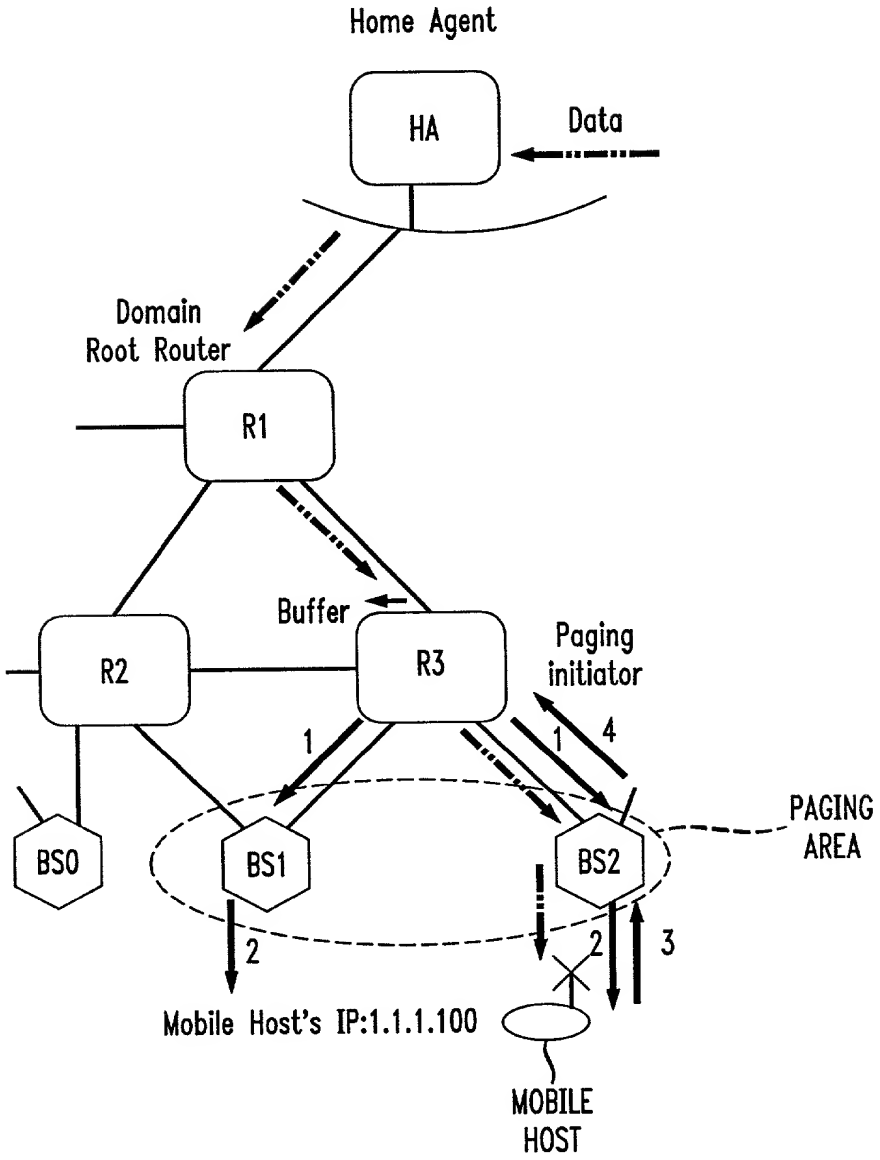

Home Agent
HA
Data
Domain
Root Router
R1
Buffer
R2
R3
Paging
initiator
1
4
1
PAGING
AREA
BS0
BS1
BS2
2
2
3
Mobile Host's IP:1.1.1.100
MOBILE
HOST

FIG. 5

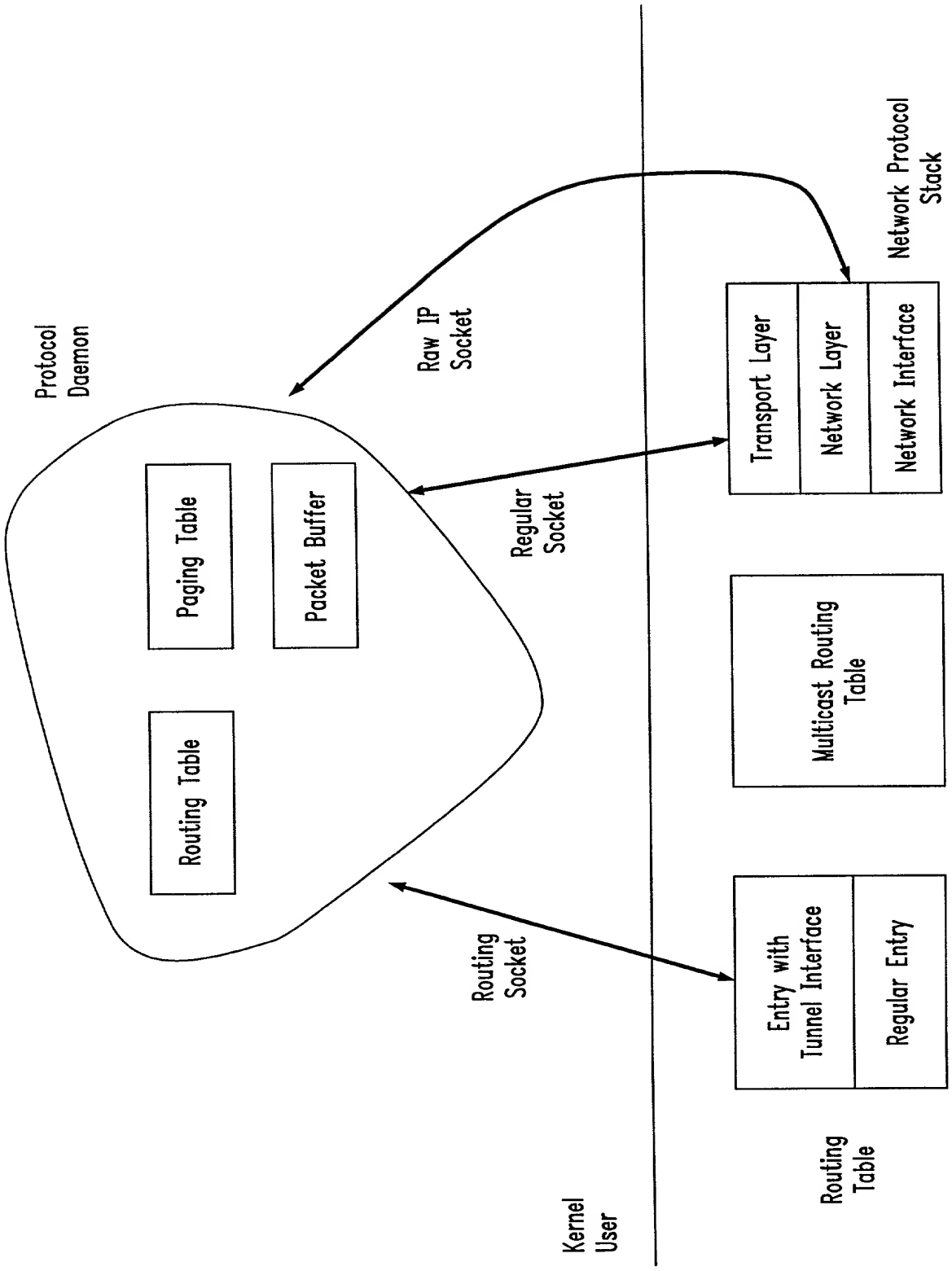

Protocol Daemon
Paging Table
Packet Buffer
Routing Table
Raw IP Socket
Regular Socket
Routing Socket
Network Protocol Stack
Transport Layer
Network Layer
Network Interface
Multicast Routing Table
Entry with Tunnel Interface
Regular Entry
Routing Table
Kernel
User

FIG. 6

TABLE I
PAGING PROCESSING TIMES IN MILLISECONDS

Router initiated (HA)	Fixed (found)	Fixed (not)	Last-loc. (found)	Last-loc. (not)	Hier. (found)	Hier. (not)
init_page_request (router)	0.173	0.173	0.323	0.316	0.196	0.203
retry_page_request (router)	–	–	–	0.157	–	0.155
recv_init_page_request (bs)	0.080	0.080	0.082	0.068	0.079	0.066
recv_page_response (bs)	0.378	0.378	0.331	0.317	0.334	0.316
recv_page_response (router)	0.279	0.279	0.190	0.193	0.204	0.215
Base station initiated (FA)						
init_page_request (bs)	0.197	0.199	0.183	0.189	0.197	0.213
retry_page_request (bs)	–	–	–	0.117	–	0.118
recv_init_page_request (bs)	0.106	0.113	–	0.114	0.106	0.114
recv_page_response (bs)	0.237	0.233	0.251	0.234	0.249	0.232
recv_page_response (router)	–	0.429	–	0.413	–	0.428

FIG. 7A

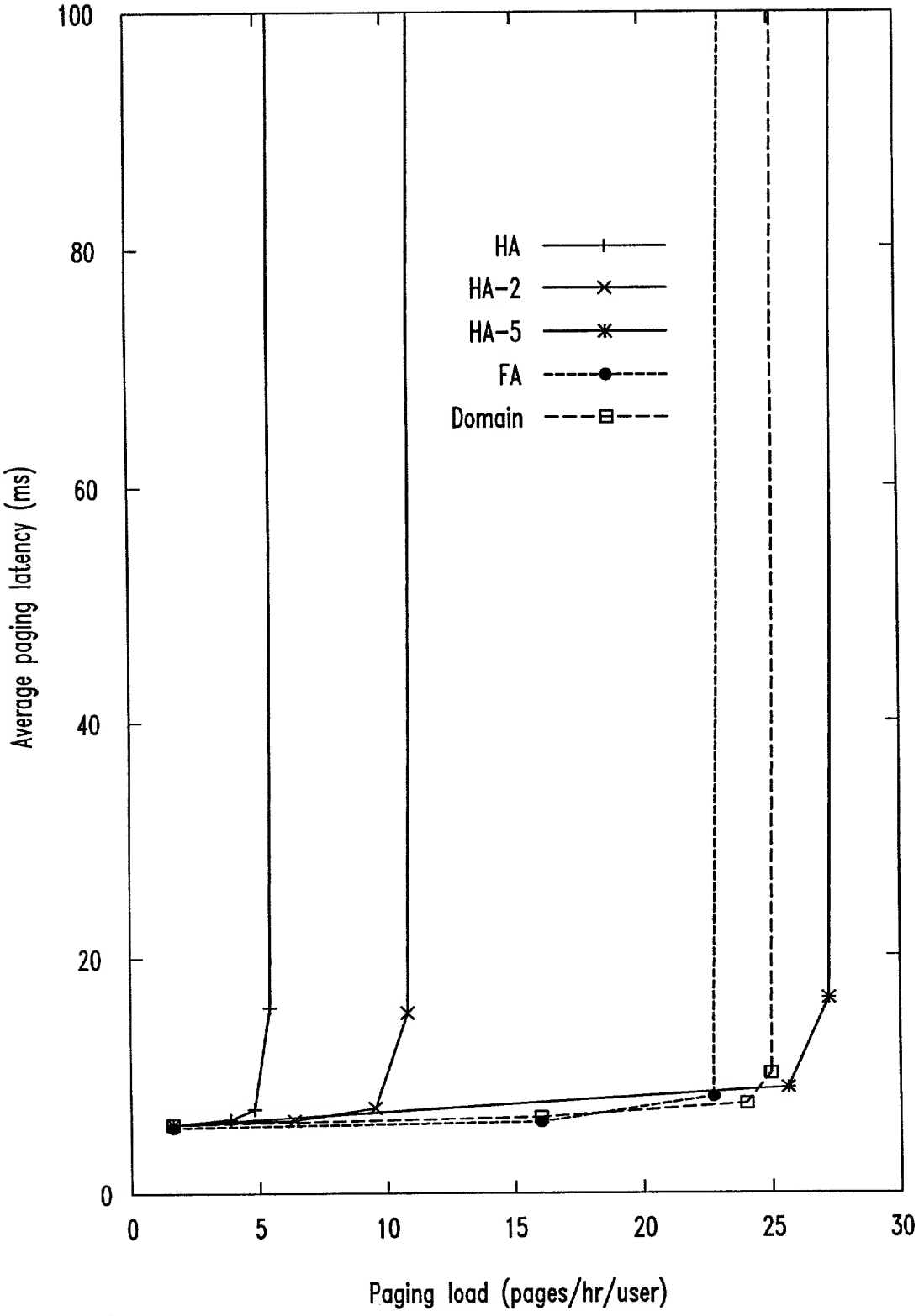

100
80
60
40
20
0
0
5
10
15
20
25
30
Average paging latency (ms)
Paging load (pages/hr/user)
HA
HA-2
HA-5
FA
Domain

FIG. 7B

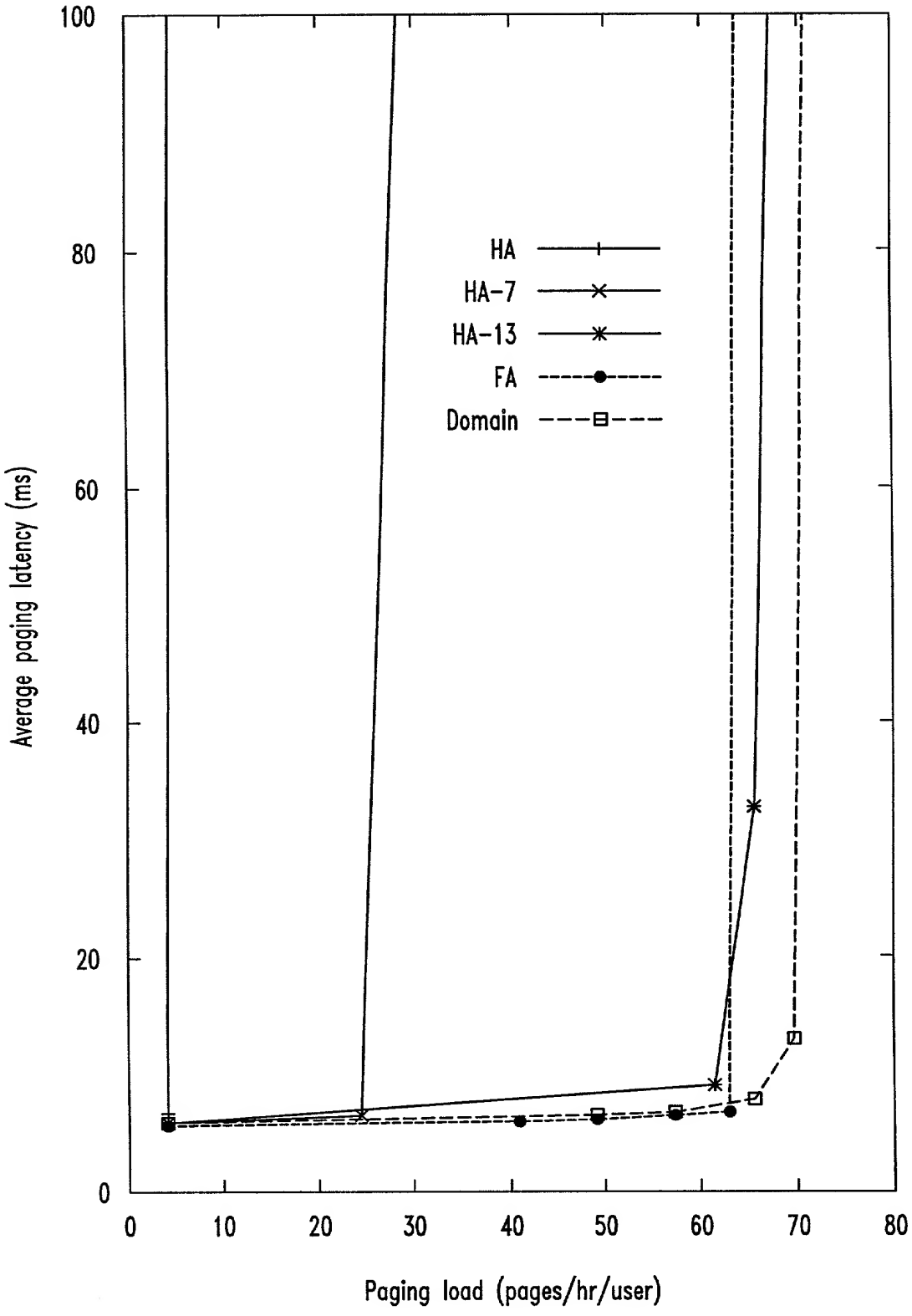

100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
Average paging latency (ms)
Paging load (pages/hr/user)
HA
HA-7
HA-13
FA
Domain

FIG. 8A

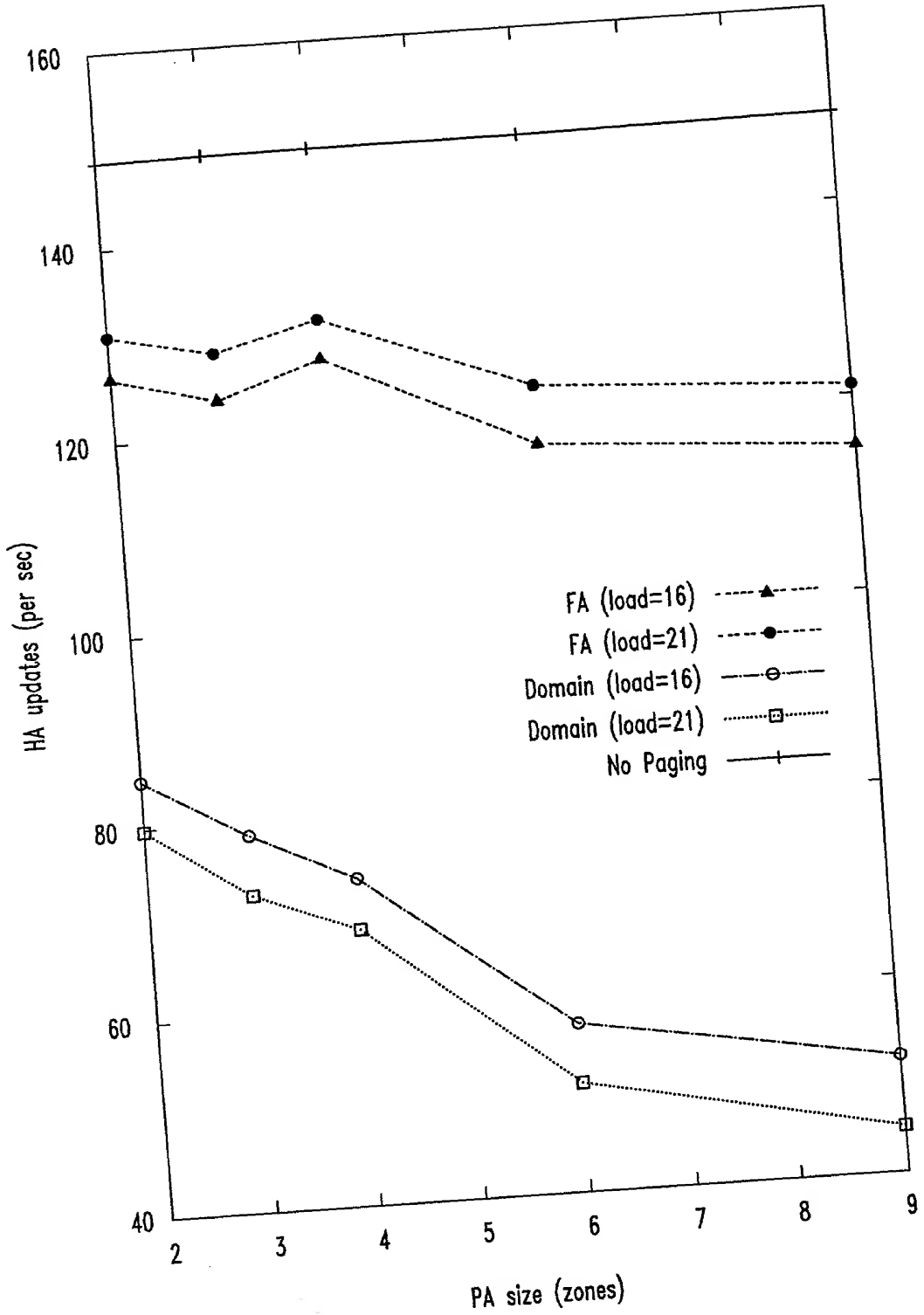

160
140
120
100
80
60
40
HA updates (per sec)
2
3
4
5
6
7
8
9
PA size (zones)
FA (load=16)
FA (load=21)
Domain (load=16)
Domain (load=21)
No Paging

FIG. 8B

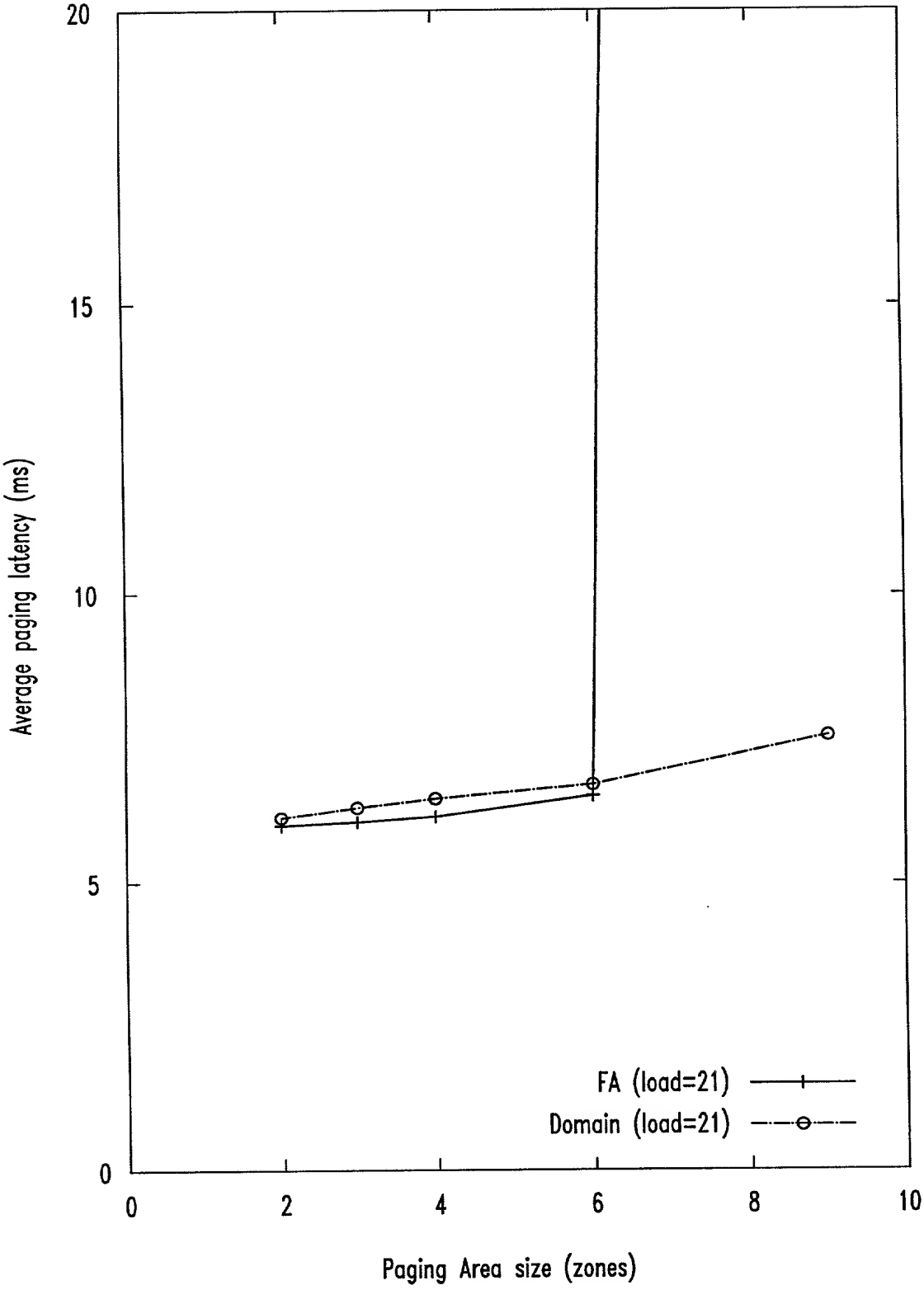
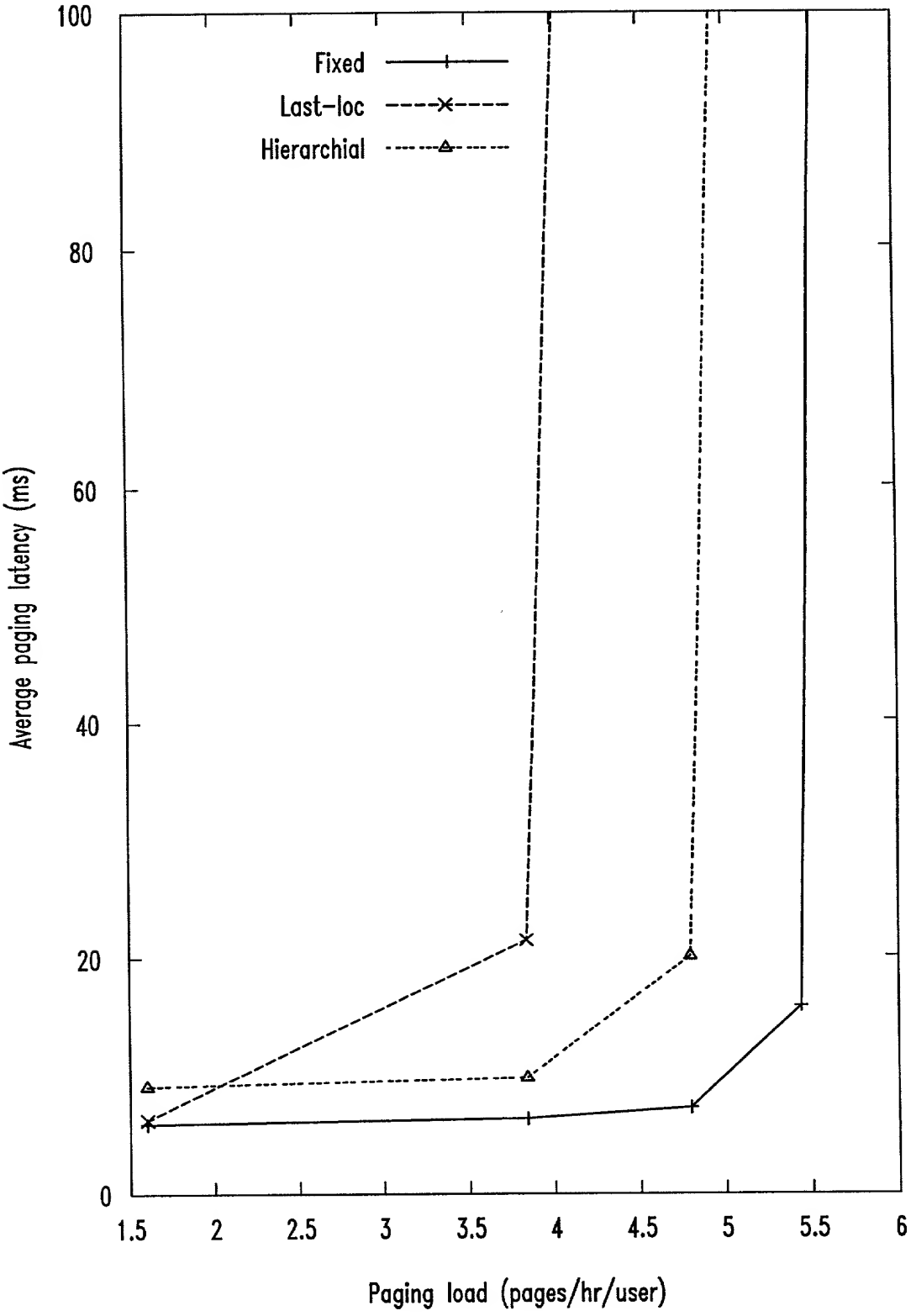

20
15
10
5
0
0
2
4
6
8
10
Average paging latency (ms)
Paging Area size (zones)
FA (load=21)
Domain (load=21)

FIG. 9A



"EXPRESS MAIL" EL 809 420 840

FIG. 9B

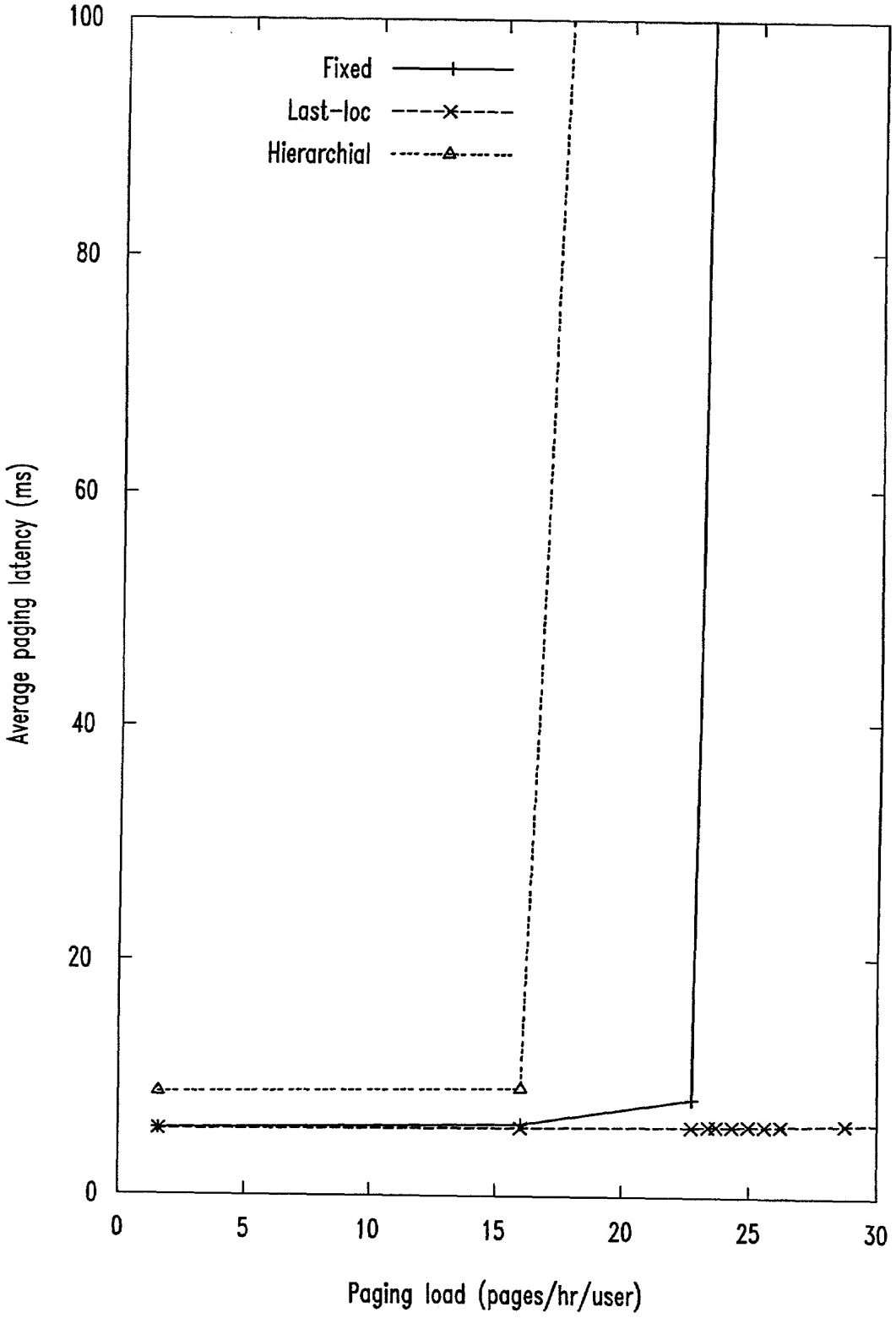

Fixed
Last-loc
Hierarchial
Average paging latency (ms)
Paging load (pages/hr/user)
0
20
40
60
80
100
0
5
10
15
20
25
30

FIG. 9C

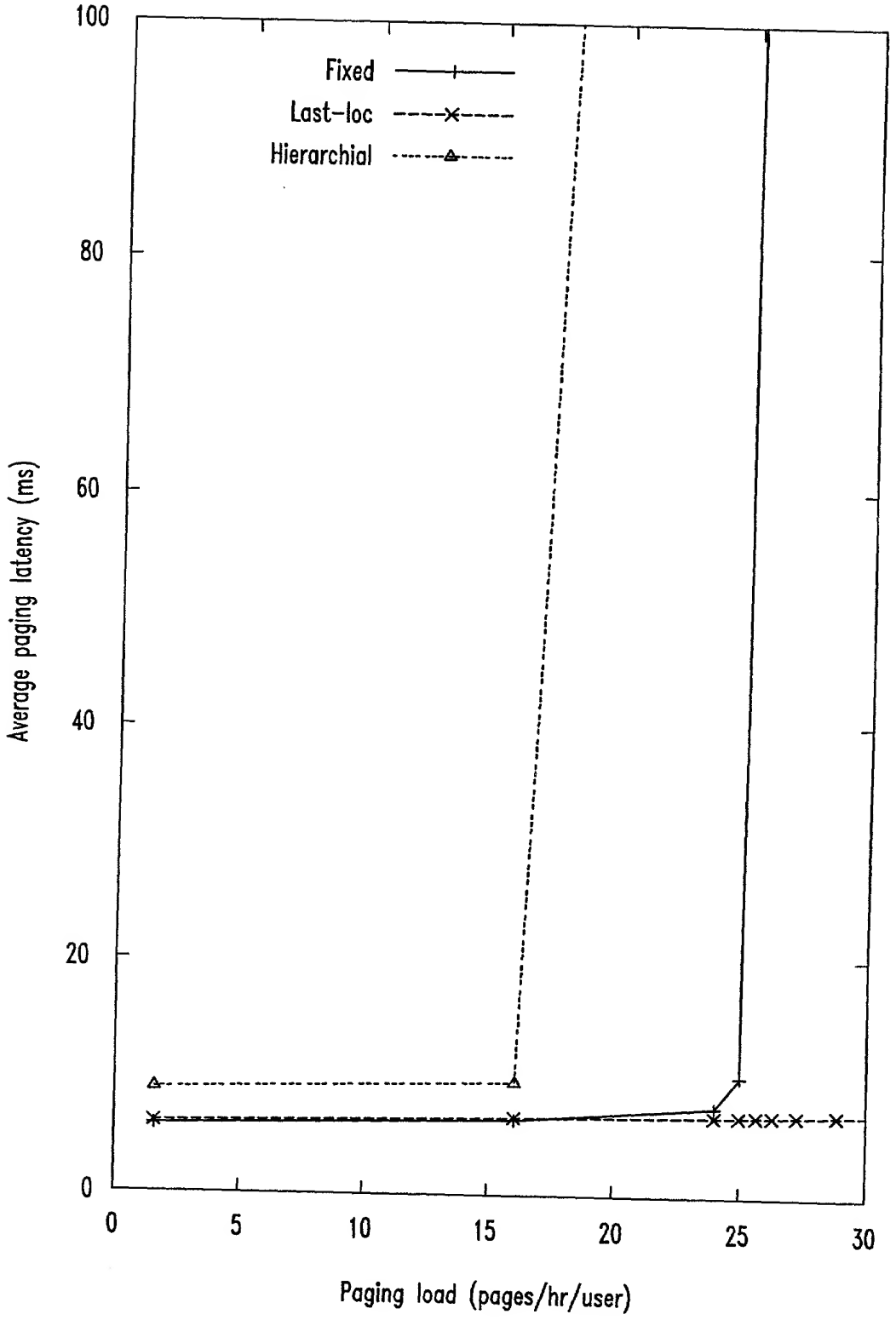

Fixed
Last-loc
Hierarchial
Average paging latency (ms)
Paging load (pages/hr/user)
0
20
40
60
80
100
0
5
10
15
20
25
30

FIG. 9D

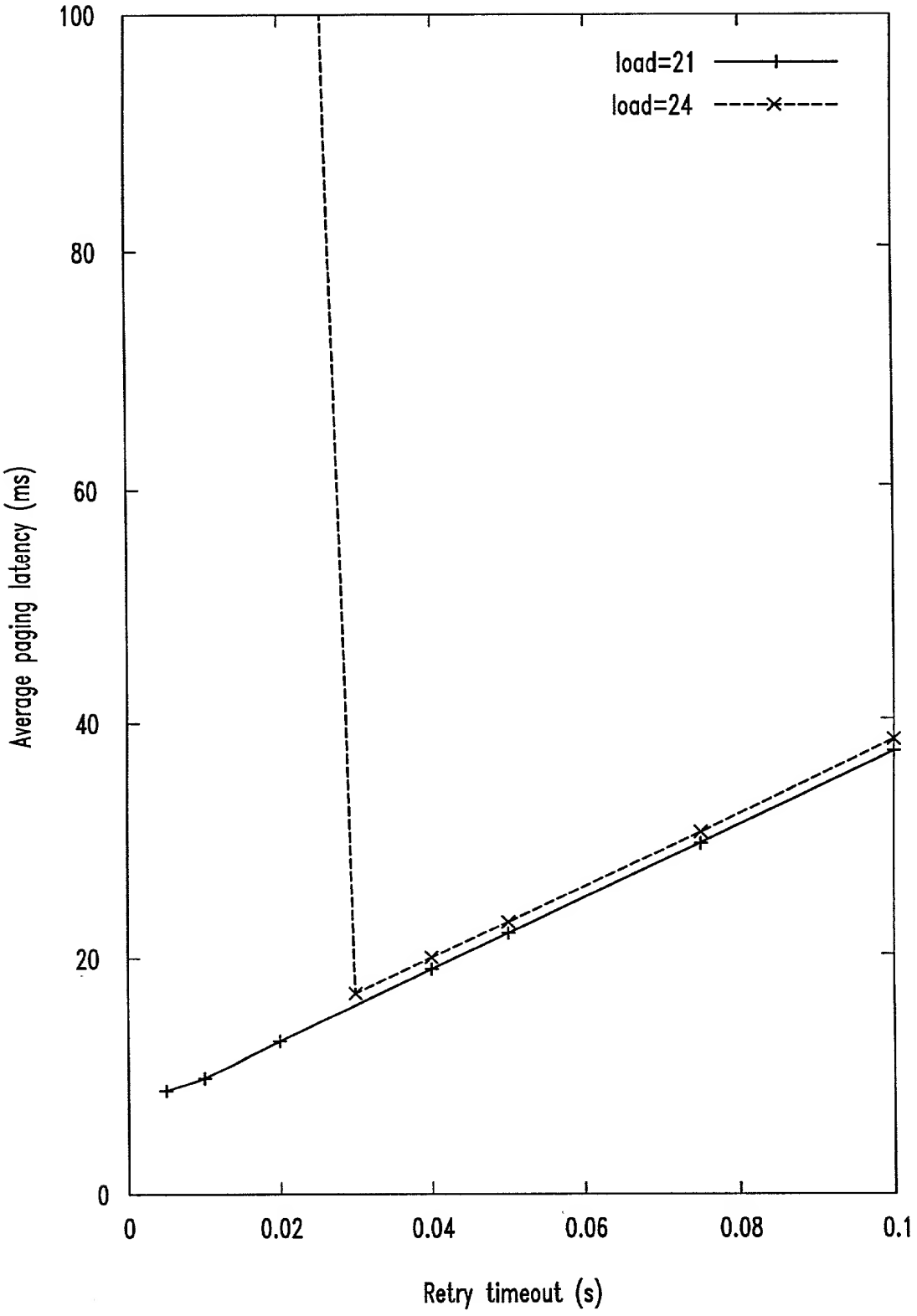
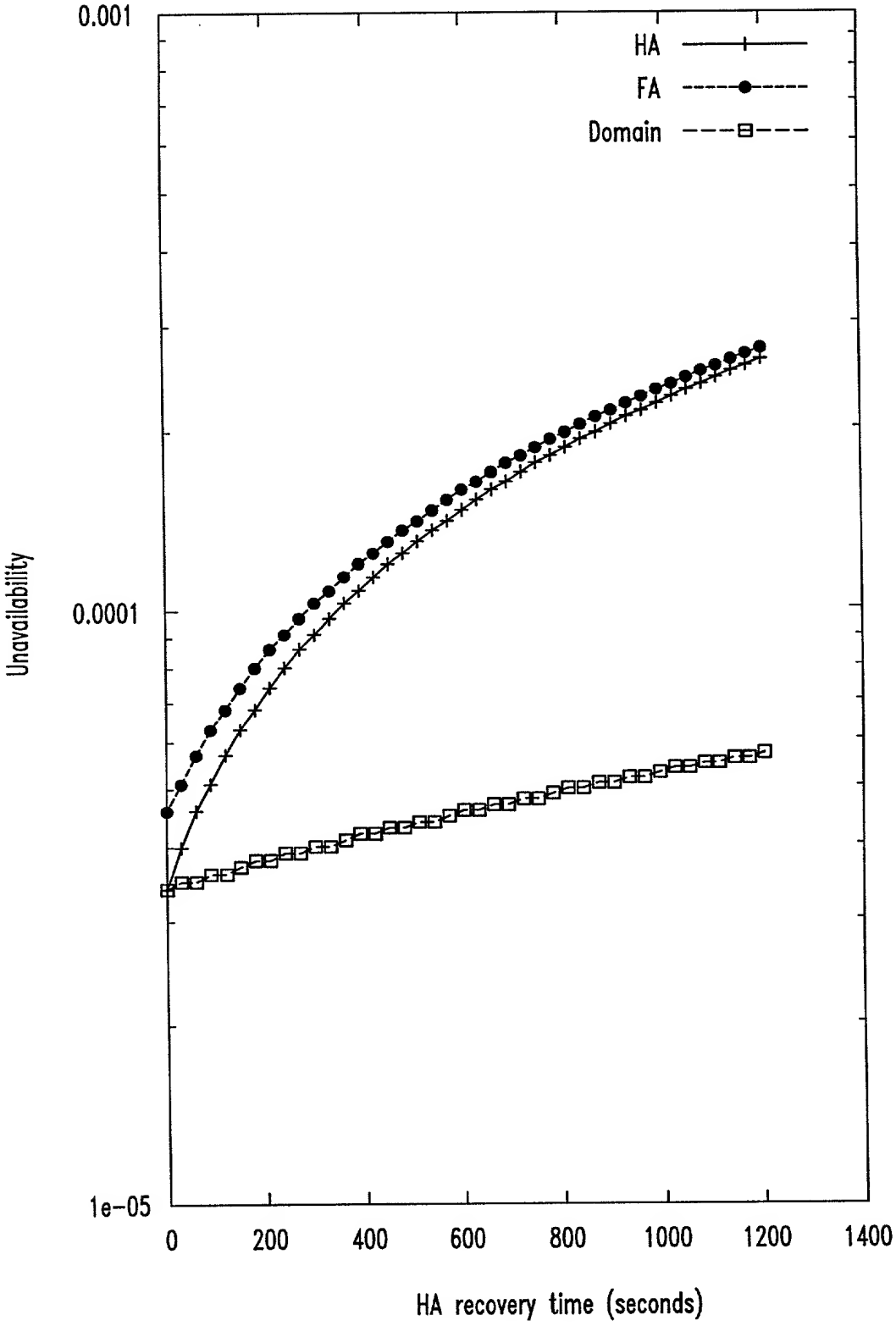

load=21
load=24
Average paging latency (ms)
Retry timeout (s)
0
20
40
60
80
100
0
0.02
0.04
0.06
0.08
0.1

FIG. 10A



"Express Mail" EL 809 420 865 US

FIG. 10B

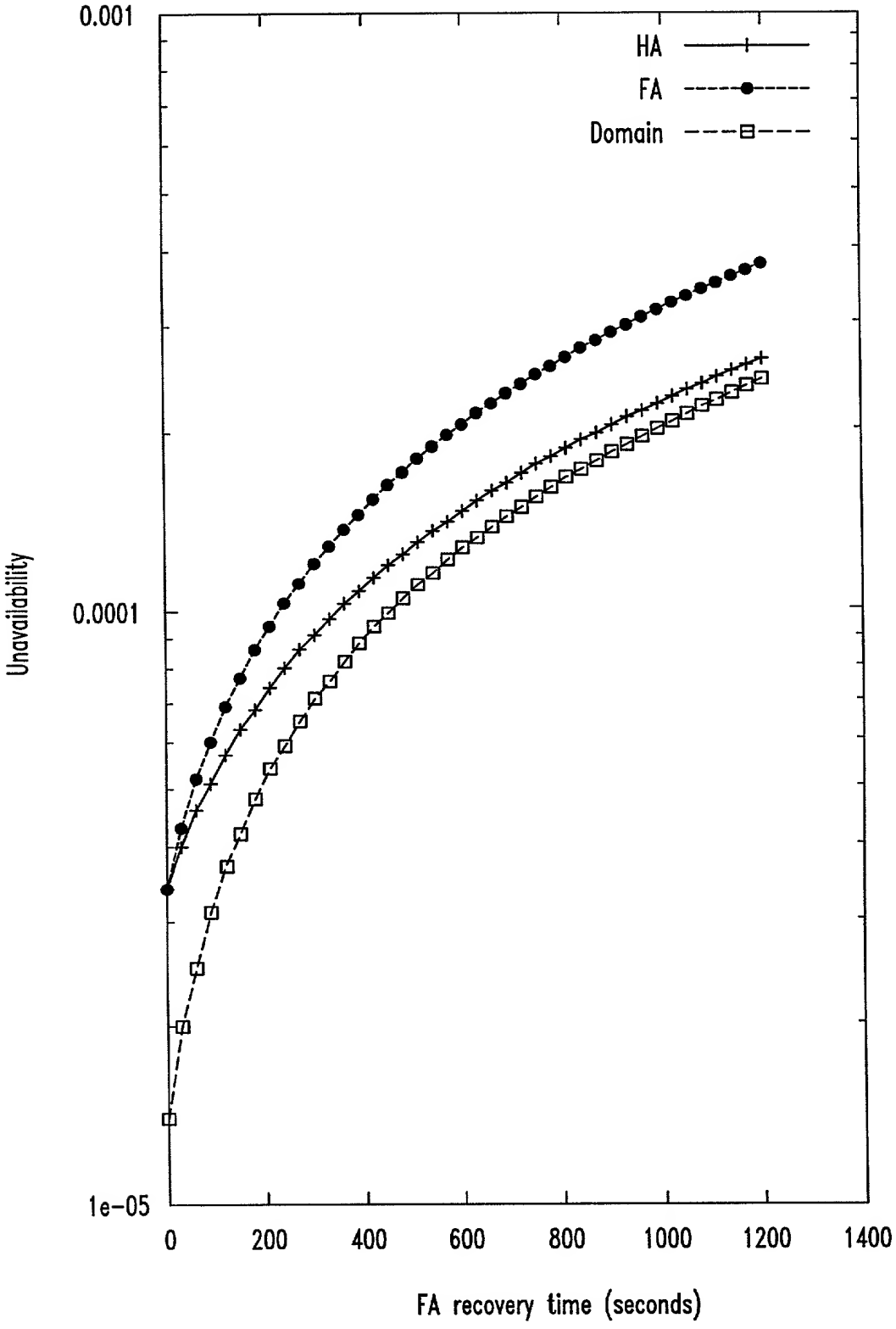

0.001
0.0001
1e-05
Unavailability
HA
FA
Domain
0
200
400
600
800
1000
1200
1400
FA recovery time (seconds)

FIG. 11

ROUTER PROCESSING FOR A GIVEN MOBILE HOST

Routing entry	Paging entry	Host state	Router action
Y	Y/N	Active	Regular IP forwarding
N	Y	Standby	Paging processing
N	N	Null	Drop if no default route

FIG. 12

```
1. Receive protocol message from neighbor with
      (MH IP ADDRESS, MGA) on Port A
2. If I am the Domain Root Router
3.    Set entry to (MH IP ADDRESS → MGA, Port A)
4. else
5.    Set entry to (MH IP ADDRESS → MGA, Port A)
6.    Forward to upstream neighbor along default route
7. endif
```

Paging update processing in base station/router

FIG. 13

```
1. IP packet for MH arrives at node with
       entry (MH IP address → MGA, Port A)
2. if (packet arrives from default route port
       or I am Domaine root Router)
3.  if ((no refresh on Port A) /* Failure */
4.       or (page queue < β)/*lightly loaded?*/
5.       or (I am a base station)) /* Initiate Paging */
6.           buffer packet and send page to MGA
7.           increase retry counter and set retry timer
8.  else       /* Push paging initiation downstream */
9.           route the packet through Port A
10.  endif
11. else
12.  forward packet along default route to DRR
13. endif
```

Paging initiation in base station/router

FIG. 14

```
1. Receive protocol message with from neighbor
     (MH IP ADDRESS, MGA) on Port A
2. If I am the paging initiator
3.  Set entry to (MH IP ADDRESS → Port A)
4.  Forward buffered packets
5. else
6.  Set entry to (MH IP ADDRESS → Port A)
7.  Forward response hop-by-hop towards initiator
8. endif
```

TOSHIBA 5004350

FIG. 15A

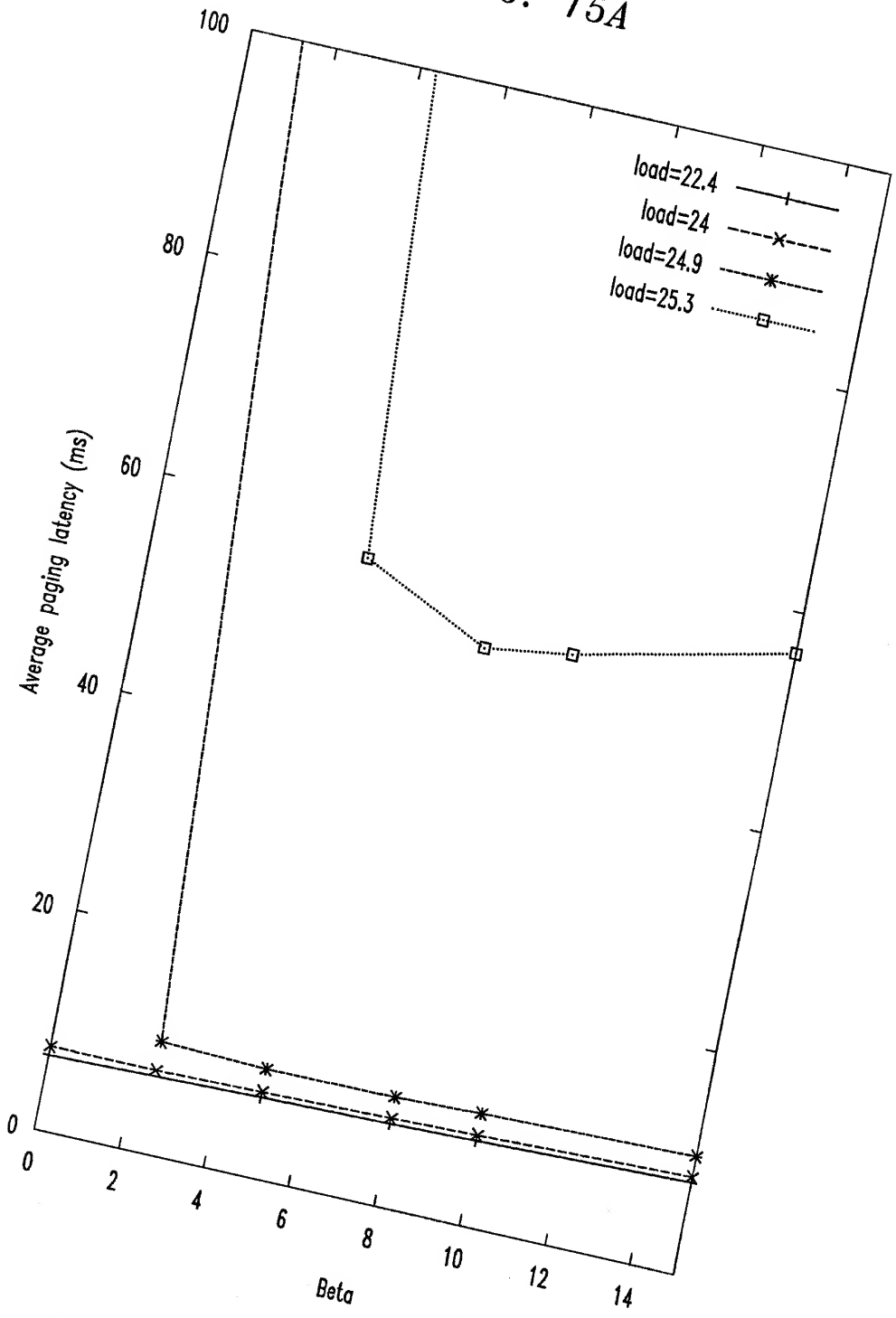
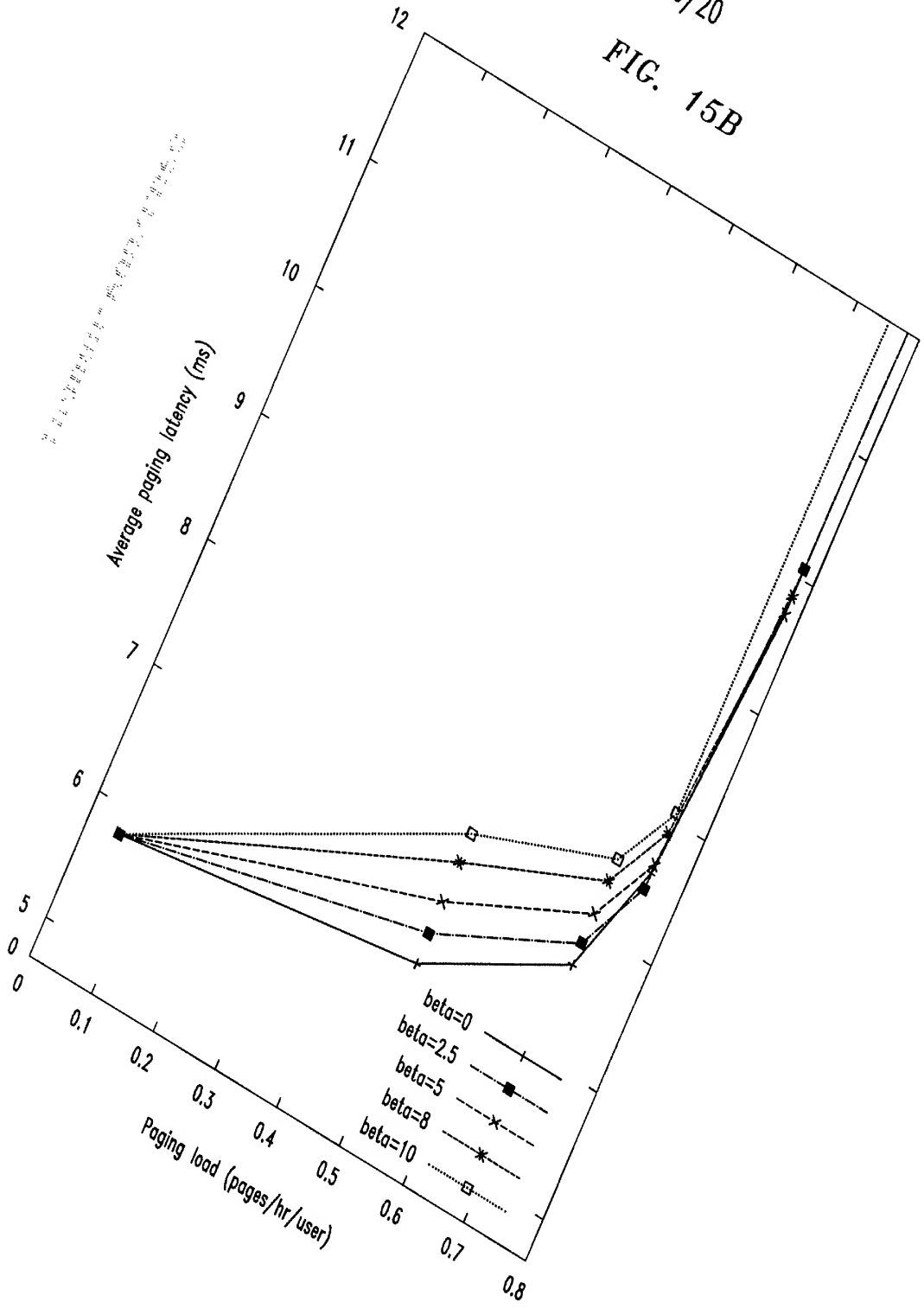

100
80
60
40
20
0
Average paging latency (ms)
0
2
4
6
8
10
12
14
Beta
load=22.4
load=24
load=24.9
load=25.3

FIG. 15B


Average paging latency (ms)
12
11
10
9
8
7
6
5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Paging load (pages/hr/user)
beta=0
beta=2.5
beta=5
beta=8
beta=10